

Army Research Laboratory

Aberdeen Proving Ground, MD 21005-5068

ARL-TR-1271

December 1996

An Efficient Technique for the Collection and Analysis of Fragment Mass Distributions From Fragmenting Munitions

J. Terrence Klopchic

Survivability/Lethality Analysis Directorate, ARL

Abstract

A fundamental step in evaluation of warhead performance is the characterization of fragments emitted during warhead detonation. The emitted fragments must be captured, a process made difficult by their high initial speeds; however, the capture must be "soft" to avoid breaking the fragments into pieces, thus changing the mass distribution. Customary techniques involve the capture in sheets of soft building material ("Celotex"), an expensive technique. As a result, a test series customarily consists of only a few rounds.

This report presents a new technique which uses hay for the capture and recovery of fragments for those cases in which the data required include the total distribution of masses, but not the partial distributions by angle. This capture technique does not preserve angular information after capture. On the other hand, the use of hay as a stopping medium provides exceptional savings in materials and labor. As a result, a test series was run at approximately 20% of the cost of a comparable series employing the customary "Celotex" technique.

Acknowledgments

The author would like to acknowledge the thorough and professional work done by Mr. Harry Reeves and the field crew of the Energetic Materials Research and Testing Center (EMRTC), Socorro, New Mexico. Mr. Reeves and EMRTC demonstrated a willingness to “go the extra mile” to assure that the data gathered for this project were complete and of exceptional quality.

Finally, the consultation and support of Mr. James O'Bryon, currently in the Office of the Secretary of Defense, Director of Operational Test and Evaluation, are recognized and appreciated.

This page intentionally left blank

Contents

Acknowledgments	iii
List of Figures	vii
I. Introduction	1
II. Considerations and Pre-Testing	2
III. Experimental Setup and Procedure	3
IV. Lessons Learned and Suggested Improvements/Extensions of the Technique	7
V. Summary	9
Distribution List	11
Report Documentation Page	15

This page intentionally left blank

List of Figures

1	Stopping Power Experiment. Plan View	3
2	Fragment Collection Setup. Side View	4
3	Witness Panel and Floor Plate. Oblique View	4
4	Witness Panel and Floor Plate. Front View	5
5	Collection Stack. Oblique View	5
6	Collection Stack. Front Closeup	6
7	Post-Shot Configuration. Plan View	8
8	A Binned Collection Stack. Plan View	9

This page intentionally left blank

I. Introduction

A fundamental step in evaluation of warhead performance is the characterization of fragments emitted during warhead detonation. This characterization presents several outstanding experimental difficulties. The emitted fragments must be captured, a process made difficult by their high initial speeds – commonly over 2 km/sec. However, the capture must be “soft” to avoid breaking the fragments into pieces, thus changing the mass distribution. In addition, an overriding consideration is the severe blast environment that accompanies a detonation.

The most commonly used procedure for characterizing fragments uses large stacks of a soft construction material (trade name: “Celotex”) which is commercially available in 1.2 m \times 2.4 m \times 1.27 cm (4 ft \times 8 ft \times 1/2 in) sheets. Approximately 100 such sheets are banded into a unit measuring 1.2 m \times 2.4 m \times 1.2 m (4 ft \times 8 ft \times 4 ft). These units – commonly about 100 of them – are then stacked, 4.8 m (16 ft) high, in a semicircle, called an arena, around the warhead to be detonated. When all is in place, the angular zones with respect to the axis of the warhead are marked onto the units, the warhead is detonated, and the captured fragments are analyzed.

This technique is quite expensive for two reasons. First, the Celotex material itself is quite expensive. In 1992, the cost of Celotex alone for one arena exceeded \$75,000. For this reason, it is necessary to replicate several warhead detonations in an arena before tearing it down and recovering the fragments. Unfortunately, the blast and fragment environment is so severe that an arena with a reasonable radius about the warhead can survive about three detonations. Thus, the number of fragments collected per arena is limited. In addition, the reuse of an arena for multiple shots runs the risk of losing previously collected data should a later detonation go awry.

Another significant expense is incurred in fragment recovery. In order to gather the desired data, it is necessary to manually locate each fragment, manually extract the fragment, manually clean it, weigh it, and record its weight and the polar zone in which it was recovered. Even with technical enhancements (e.g., metal detectors), the man-hour costs to recover fragments from an arena are comparable to the Celotex costs.

As a result of these expenses, it is common for a complete series to consist of as few as five shots to characterize the distribution of fragment masses from a particular type of warhead.

In 1993, the need arose to measure the differences in mass distributions between two sets of M109, 155 mm high explosive (HE) artillery projectiles.¹ Since the phenomenon being investigated may have resulted small differences in large numbers of fragments, the needed confidence in the accuracy of the data required many more than five rounds. In addition, the available funding was significantly less than that required for a typical warhead characterization series. As a result, a new technique was required for the determination of mass distributions.

This report describes the new technique. The purpose and results of the first use of the technique are reported elsewhere.¹

II. Considerations and Pre-Testing

It is essential to note that the data required in the M109, 155 mm HE artillery projectile comparison included the total distribution of masses, but not the partial distributions by angle. That is, the angular dispersion was irrelevant, allowing all fragments to be combined into a single mass distribution regardless of their individual angles of emission. Thus, the capture technique did not need to preserve angular information after capture. The technique presented here takes advantage of this loose constraint.

(Extensions of the technique to support coarse angular resolution are discussed below.)

The capture material chosen for the technique is common hay. It is a customary practice in the western United States to harvest hay (for cattle feed) in tightly packed bales measuring 1.2 m (4 ft) high by 1.2 m wide by 2.8 m long with a density of 176 to 192 kg/m³ (11 to 12 lb/ft³). Total mass of a bale is about 680 kg (1500 lb.) Previous experiments performed at the Energetic Materials Research and Testing Center (EMRTC) had shown these bales to constitute a soft recovery medium: fragments do not break during penetration of packed hay. In addition, the cost of a unit (bale) of hay, approximately \$90, is significantly less than the cost of a comparable unit of Celotex.

It remained to demonstrate that the stopping power of a unit of hay was sufficient for fragments from an M109 155 mm artillery round. For this purpose,

¹Klopčic, J. Terrence and Lynch, David D. *Static and Dynamic Characterization of the M107 (Composition B Filled) Artillery Projectile*, ARL Report, to be published.

a round was detonated in the configuration shown in Figure 1. Note that the test unit was placed in the zone of the artillery round that contains the fastest and many of the largest fragments. Post-shot analysis showed no perforation of the thin aluminum witness panel. It was therefore concluded that the stopping power of hay was sufficient for the referenced experiments.

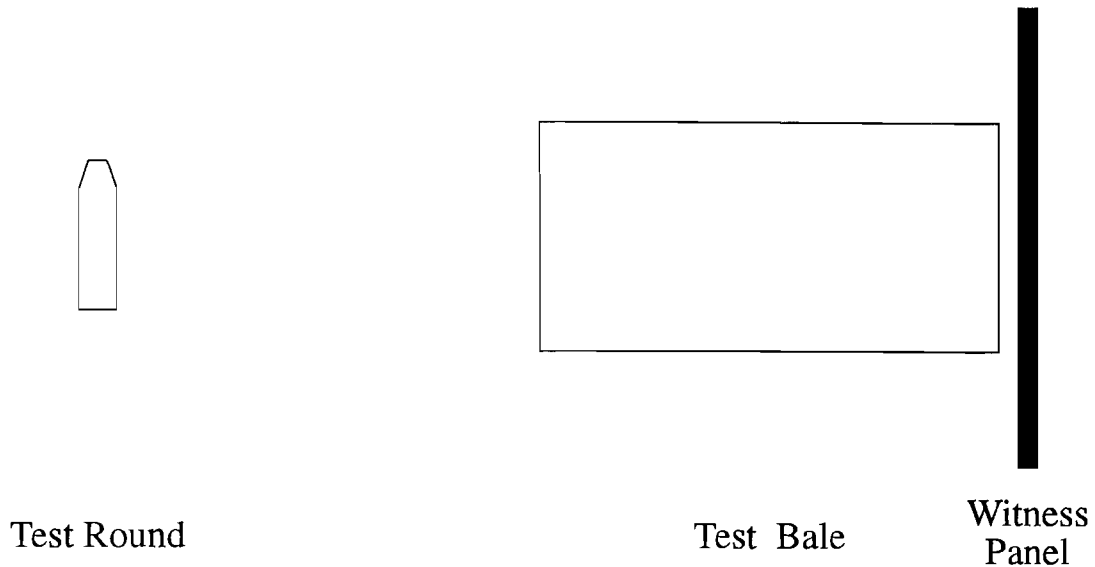


Figure 1: Stopping Power Experiment. Plan View

III. Experimental Setup and Procedure

The experimental setup for a fragment collection is depicted in Figure 2. Photographs taken during the first application of this technique are included in Figures 3 through 6.

Note that these hay bales can be stacked at least five high, giving a vertical span of over 6 m.

As explained below, it is essential to build the collection stack on a smooth solid surface, as provided by the steel floor plate shown in Figure 2.

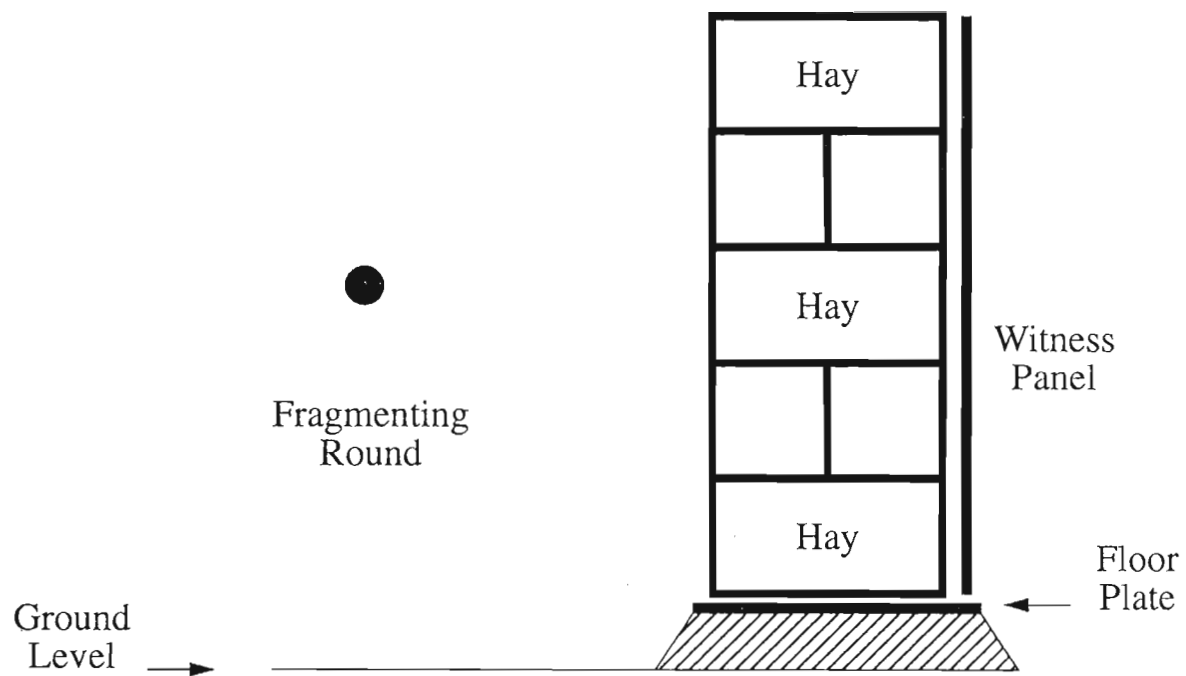


Figure 2: Fragment Collection Setup. Side View



Figure 3: Witness Panel and Floor Plate. Oblique View



Figure 4: Witness Panel and Floor Plate. Front View



Figure 5: Collection Stack. Oblique View



Figure 6: Collection Stack. Front Closeup

It is also desirable to prevent fragments which impact the ground from ricocheting into the collection medium.² In this experiment, the collection medium was raised above the ground such that probable ricochet angles were excluded.

Since the fragment collection technique described in this report may be applicable to many different fragmentation experiments, the particulars of round placement and detonation will not be discussed here. In particular, the placement and detonation employed in the first use of this collection technique are reported elsewhere.¹

Following detonation of the round(s), the procedure continues as follows.

1. Ground plates are laid on the ground surrounding the fragment-containing hay. This is depicted in Figure 7.
2. The hay is then burned, with the residue (ash and fragments) collected by the floor plate and ground plates.
3. After the hay has been completely burned, the residue is carefully swept from the floor plate and ground plates onto plywood sheets.
4. The fragments are then magnetically recovered from the ash.
5. The recovered fragments are then cleaned, weighed, and analyzed using standard techniques.

IV. Lessons Learned and Suggested Improvements/Extensions of the Technique

In the process of conducting the first experiments with this technique, two outstanding errors in procedure were made which caused the need for reruns.

1. When the collection stack of hay is burned, the fire releases the baling bands, allowing the bales to burst open. This action causes some of the

¹Klopacic, J. Terrence and Lynch, David D. *Static and Dynamic Characterization of the M107 (Composition B Filled) Artillery Projectile*, ARL Report, to be published.

²*Testing and Data Reduction Procedures for High-Explosive Munitions*. Joint Munitions Effectiveness Manual 61A1-3-7, Revision 2, May 1989.

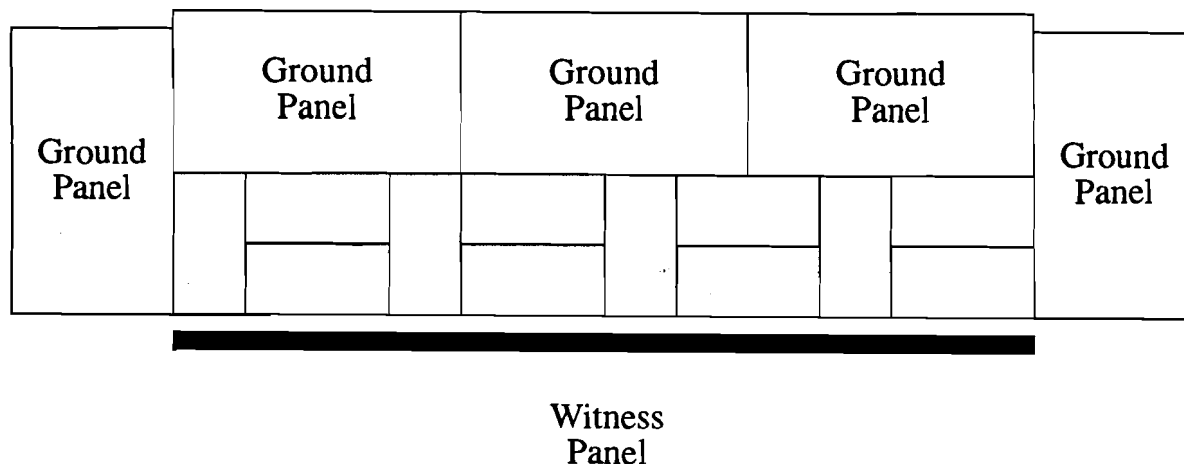


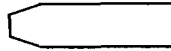
Figure 7: Post-Shot Configuration. Plan View

2. An attempt was made to replace the hay with less expensive/more readily available straw. Although the fragment retardation properties of straw are quite comparable to hay, the burning characteristics are not. Rather, when straw is burned, it produces a sticky residue which solidifies into hard masses in which the fragments are embedded. This phenomenon significantly impedes the subsequent separation and recovery of the fragments.

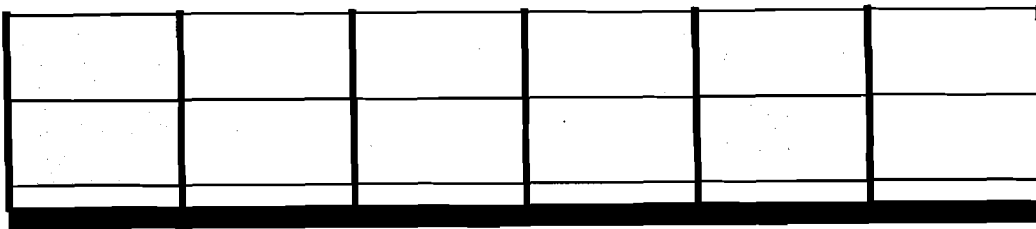
Suggested improvements/extensions of the technique include the following.

1. To avoid the potential loss of fragments due to the tumbling of burning bales beyond the ground plates, the collection stack could be surrounded by heavy wire ("Cyclone") fencing prior to burning.
2. It would be possible to construct bins within the stack as shown in Figure 8. This configuration, in conjunction with use of fencing during the burning process, would allow a coarse separation of fragment collection by angular zone. It is pointed out, however, that construction of angular zones of sufficient resolution to replace traditional Celotex arenas appears highly impractical.

3. A different realization of this fragment collection technique involves a different alignment of test round and collection stack. In this realization, a 2.8 m (8 ft) deep trench is dug into the ground and lined with the witness panel. The collection stack is then laid into the trench such that the upper edge of the stack is at ground level. This variation of the technique avoids the difficulties involved in tumbling bales. However, it introduces difficulties in test round placement, and may increase setup costs.



Fragmenting Round



Witness Panel with
Zone Separators

Figure 8: A Binned Collection Stack. Plan View

V. Summary

The technique described in this report was successfully used to collect fragments from explosively detonated M107 155 mm artillery projectiles. The technique proved to be significantly less expensive than the traditional Celotex method of fragment collection. The technique also proved to be highly efficient, resulting in rapid turnaround time. As described in Reference 1, the efficiency and lower cost allowed the collection of four times as much data at approximately one fifth the cost of the standard fragment collection technique.

On the other hand, the application of this technique did not require angular separation of the fragments. Had such information been required, at the common (5 degree) level of resolution, this technique would not apply.

NO. OF COPIES	ORGANIZATION
2	DEFENSE TECHNICAL INFO CTR ATTN DTIC DDA 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
1	HQDA DAMO FDQ ATTN DENNIS SCHMIDT 400 ARMY PENTAGON WASHINGTON DC 20310-0460
1	US MILITARY ACADEMY MATH SCI CTR OF EXCELLENCE DEPT OF MATHEMATICAL SCI ATTN MDN A MAJ DON ENGEN THAYER HALL WEST POINT NY 10996-1786
1	DIRECTOR US ARMY RESEARCH LAB ATTN AMSRL CS AL TP 2800 POWDER MILL RD ADELPHI MD 20783-1145
1	DIRECTOR US ARMY RESEARCH LAB ATTN AMSRL CS AL TA 2800 POWDER MILL RD ADELPHI MD 20783-1145
3	DIRECTOR US ARMY RESEARCH LAB ATTN AMSRL CI LL 2800 POWDER MILL RD ADELPHI MD 20783-1145
<u>ABERDEEN PROVING GROUND</u>	
2	DIR USARL ATTN AMSRL CI LP (305)

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	OSD OUSD AT STRT TAC SYS ATTN DR SCHNEITER 3090 DEFNS PENTAGON RM 3E130 WASHINGTON DC 20301-3090	1	ARMY RESEARCH LABORATORY ATTN AMSRL SL PROGRAMS AND PLANS MGR WSMR NM 88002-5513
1	ASST SECY ARMY RESEARCH DEVELOPMENT ACQUISITION ATTN SARD ZD RM 2E673 103 ARMY PENTAGON WASHINGTON DC 20310-0103	1	ARMY RESEARCH LABORATORY ATTN AMSRL SL E MR MARES WSMR NM 88002-5513
1	ASST SECY ARMY RESEARCH DEVELOPMENT ACQUISITION ATTN SARD ZP RM 2E661 103 ARMY PENTAGON WASHINGTON DC 20310-0103	1	ARMY TRADOC ANL CTR ATTN ATRC W MR KEINTZ WSMR NM 88002-5502
1	ASST SECY ARMY RESEARCH DEVELOPMENT ACQUISITION ATTN SARD ZS RM 3E448 103 ARMY PENTAGON WASHINGTON DC 20310-0103	1	ARMY TRNG & DOCTRINE CMND ATTN ATCD B FT MONROE VA 23651
1	ASST SECY ARMY RESEARCH DEVELOPMENT ACQUISITION ATTN SARD ZT RM 3E374 103 ARMY PENTAGON WASHINGTON DC 20310-0103		<u>ABERDEEN PROVING GROUND</u>
1	UNDER SEC OF THE ARMY ATTN DUSA OR RM 2E660 102 ARMY PENTAGON WASHINGTON DC 20310-0102	1	CDR USATECOM ATTN: AMSTE-TA
1	ASST DEP CHIEF OF STAFF OPERATIONS AND PLANS ATTN DAMO FDZ RM 3A522 460 ARMY PENTAGON WASHINGTON DC 20310-0460	2	DIR USAMSAA ATTN: AMXSY-ST AMXSY-D
1	DEPUTY CHIEF OF STAFF OPERATIONS AND PLANS ATTN DAMO SW RM 3C630 400 ARMY PENTAGON WASHINGTON DC 20310-0400	4	DIR USARL ATTN: AMSRL-SL, J WADE (433) M STARKS (433) AMSRL-SL-C, J BEILFUSS (E3331) AMSRL-SL-B, P DEITZ (328)

NO. OF
COPIES ORGANIZATION

1 OSD DOT&E/LFT
 ATTN J O'BRYON
 1700 DEFENSE PENTAGON
 WASHINGTON DC 20301-1700

ABERDEEN PROVING GROUND

DIR USARL

ATTN AMSRL-SL-BA, J. A. MORRISSEY
 AMSRL-SL-BG, A. L. YOUNG
 AMSRL-SL-BL,
 D. D. LYNCH
 M. E. RITONDO
 AMSRL-SL-BS,
 D. C. BELY
 N. J. GERRI
 R. L. GROTE
 P. J. KUSS
 D. N. NEADES
 M. L. O'BRIEN
 AMSRL-SL-BV, R. S. SANDMEYER
 AMSRL-WT-WM, T. G. BROWN JR.

This page intentionally left blank

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project(0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE December 1996	3. REPORT TYPE AND DATES COVERED Final, March 1993-March 1994	
4. TITLE AND SUBTITLE An Efficient Technique for the Collection and Analysis of Fragment Mass Distributions From Fragmenting Munitions			5. FUNDING NUMBERS PR: 1L162618AH80	
6. AUTHOR(S) J. Terrence Klopccic				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory ATTN: AMSRL-SL-BS Aberdeen Proving Ground, MD 21005-5068			8. PERFORMING ORGANIZATION REPORT NUMBER ARL-TR-1271	
9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES) U.S. Army Research Laboratory IBID OSD(A)/T&E-L&MS			10.SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) A fundamental step in evaluation of warhead performance is the characterization of fragments emitted during warhead detonation. The emitted fragments must be captured, a process made difficult by their high initial speeds; however, the capture must be "soft" to avoid breaking the fragments into pieces, thus changing the mass distribution. Customary techniques involve the capture in sheets of soft building material ("Celotex"), an expensive technique. As a result, a test series customarily consists of only a few rounds. This report presents a new technique which uses hay for the capture and recovery of fragments for those cases in which the data required include the total distribution of masses, but not the partial distributions by angle. This capture technique does not preserve angular information after capture. On the other hand, the use of hay as a stopping medium provides exceptional savings in materials and labor. As a result, a test series was run at approximately 20% of the cost of a comparable series employing the customary "Celotex" technique.				
14. SUBJECT TERMS arena testing, fragmentation, tests, fragments			15. NUMBER OF PAGES 18	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

This page intentionally left blank